SHOULD ATHLETES USE THEIR STRONGER LEG ON THE FRONT BLOCK DURING THE SPRINT START?

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The aim of this study was to understand force production differences when alternating feet on the starting blocks. The hypothesis was that the dynamically stronger leg should be on the front. Utilising force plates, eight male athletes performed starts alternating the front foot on the block, as well as single leg vertical countermovement jumps to test dynamic strength. In total, 121 starts were analysed. At the group level, there were no statistically significant differences in any of the force variables between dynamically stronger and weaker leg. The results raised some doubts to the theory that the stronger leg should be on the front block during the sprint start. Consequently, the advice for coaches training developing athletes is to allow athletes to use the block settings they feel comfortable with, rather than trying to overanalyse which leg should be on the front or rear block.

KEY WORDS: sprinting, acceleration, starting blocks, track and field, dynamic strength

INTRODUCTION: Sprint start research has recently gained interest within various research groups around the world. The researchers have analysed, for example, block phase kinetics (Willwacher et al., 2013) and kinematics (Bezodis et al., 2015a), first step kinetics (Bezodis et al., 2014), body posture (Slawinski et al., 2013) and body segment co-ordination (Slawinski et al., 2010). Additionally, computer simulation studies by Bezodis et al. (2015b) and Debaere et al. (2015) have made suggestions about how to improve the performance of athletes.
All the empirical studies above have been carried out with experienced sprinters in their typical block settings with their own choice of front foot. However, it is less clear how athletes select which foot is on the front block and which one is on the rear block. Only a few studies have actually analysed the starts with alternating the feet on the front and rear blocks. Such studies have usually linked the performance with the participants' self-determined preferred leg. Further, Vagenas and Hoshizaki (1986) studied alternating feet on the blocks with association to the dynamic strength of 15 skilled sprinters. Their outcome measures, though, were various velocity variables and time to reach set distances, which have since been demonstrated to reveal inconsistent results as performance measures (Bezodis et al., 2010). Eikenberry et al. (2008) similarly investigated the effect of alternating feet on the blocks and asymmetries on reaction and movement times. Neither Vagenas and Hoshizaki (1986) nor Eikenberry et al. (2008) analysed the actual force production during the block phase and thus, there is still a lack of understanding of how changing the feet on the blocks would influence force production and overall block performance. Thus, the aim of this study was to understand key force production differences when alternating feet on the blocks. The main hypothesis based on the literature was that the dynamically stronger leg should be set on the front block.

METHODS: Eight university level male athletes (20.3 ± 2.0 years, 77.7 ± 9.0 kg) volunteered for the study. Four participants specialised in sprinting and the other four participants were jumpers, who were used to quick power production, but did not have extensive experience of using starting blocks. Participants signed an informed consent form before any data collection. Two force plates (900 mm x 600 mm, sampling at 1000 Hz, model 9287BA; Kistler Instruments Ltd, Switzerland) placed side-by-side were covered with synthetic rubber mats. Competition blocks were set as shown in Figure 1: two separate spines were used, one on each force plate with the foot plates positioned so that the lateral space between them equalled the width of the spine. This allowed forces from each leg to be collected and analysed in a normal sprint start situation. CODA markers (sampling at 200 Hz; Charnwood Dynamics Ltd., United Kingdom) were attached to the nail of the index fingers to analyse the hand movement during the start.

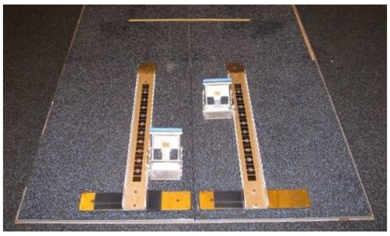

Figure 1. Starting block set up allowing force production to be analysed for each leg separately.

The participants carried out a brief warm-up followed by some stretching before practising the starts. Inexperienced starters were provided with coaching information before and during the warm-up starts so that they were sufficiently able to use the blocks during the actual data collection. All experienced starters used their own block settings with inexperienced starters adopting the basic coaching set up consisting of two foot lengths from the starting line to the front block and an additional third foot length to the rear block. All participants used their own spikes during the data collection and they were asked which their preferred front leg was.

Each participant performed four sets of five starts of 5 m alternating the front foot on the block for each set. The recovery was 2-3 minutes between each trial. The block settings were kept respectively the same for alternated feet placings. An experienced starter provided the normal starting commands followed by an electronic beep, which synchronously started the data collection and acted as a starting signal to the participants. After the starts, the participants performed three single leg vertical countermovement jumps for each leg in trainers on a force plate. The dynamically stronger/weaker leg was analysed from the countermovement jumps. For each leg separately, the maximum force production value was found for each jump and averaged over the three jumps, and the stronger/weaker leg was determined.

The force and hand movement data from the start trials were analysed with a custom written Matlab script (The MathWorks, USA). The force data were first filtered with a fourth order Butterworth filter with a cut-off frequency set at 70 Hz based on residual analysis carried out for all trials of one participant. Graham-Smith et al. (2014) demonstrated that hands (in the set position and at the start of the sprint) had a substantial influence on force production, especially in the vertical direction. Consequently, the force data were corrected based on the movement acquired from the finger markers. For example, while the participant was stationary in the set position, the vertical force supplied by the hands was the difference between the actual body weight and the combined vertical forces from the force plates. This difference was calculated and used as the initial hands force. From the moment the participant began to move, the percentage body weight supported by the hands was estimated and added to the vertical combined forces of the legs (proportionally and inversely to the acceleration of the finger markers until the hands had lifted from the track, at which point the hands force against the ground was zero). Several force production variables were analysed from both plates in the horizontal, vertical and resultant directions: the maximum forces produced, the time to achieve the maximum forces from the start of force production, the peak instantaneous (force data differentiated) and average (maximum force divided by the time to achieve this force) rate of force production, and the time of peak instantaneous rate of force production. Additionally, the duration of force production, the block exit velocity (via impulses) in horizontal and vertical direction, the ratio of forces (Morin et al., 2011) and the projection angle of the centre of mass were calculated. The performance criterion used was the overall horizontal external power during the block phase based on Bezodis et al. (2010). Trials with clearly erroneous data (mainly due to finger marker accelerations) were removed from the analysis yielding six to 10 trials per leg for each participant.

Sprint start force data were reorganised to stronger leg in front - weaker leg in rear and vice versa. In total, 121 trials were included (62 trials when the stronger leg was on the front block and 59 trials when the weaker leg was on the front block). The mean values of each participant in both conditions were set for paired samples t-test to analyse statistically significant differences between the conditions (*p* <.05). In addition, within the participants, independent samples t-tests were carried out to determine whether there were individual differences between the legs.

RESULTS: The paired samples t-test did not reveal any statistically significant differences in any of the sprint start variables within the group. In the countermovement jumps, there was a statistically significant difference in maximum vertical force produced between the legs (stronger leg 1607 ± 160 N vs. weaker leg 1534 ± 150 N, t=2.999, *p*=0.020). The values from key variables are presented in table 1 below. Amongst the participants, it was noticeable that four sprinters had a substantially greater number of statistically significant differences between the legs than four non-sprinters (sprinters: 9, 20, 20 and 28, non-sprinters: 1, 4, 7 and 29 statistically significant variables). There were, however, no noticeable commonalities amongst the participants within those variables that revealed statistically significant differences, i.e. the stronger leg (defined by the countermovement jumps) produced higher maximum force on the blocks than the weaker leg for some, but lower maximum force for others. The preferred front leg was the stronger one only for 3 out of 8 participants.

Table 1. Selected key variables from the block phase with paired samples t-test results.

		Stronger leg		Weaker leg			
		Mean	SD	Mean	SD	t	*p*
Horizontal velocity at block exit (#)	[m/s]	2.99	0.14	2.98	0.16	.168	.872
Vertical velocity at block exit (#)	[m/s]	0.79	0.11	0.81	0.11	-.462	.658
Absolute external horizontal power (#)	[W]	901	139	892	162	.285	.784
Relative external horizontal power (#)	[W/kg]	11.64	1.42	11.49	1.49	.322	.757
Peak horizontal force on front block	[N]	791	100	784	67	.423	.685
Peak vertical force on front block	[N]	971	125	972	101	-.055	.958
Peak horizontal force on rear block	[N]	856	130	838	210	.381	.715
Peak vertical force on rear block	[N]	741	144	759	195	-.445	.670
Angle of projection (#)	[°]	15.5	3.8	15.3	2.4	.143	.891

as these variables are related to the centre of mass, stronger/weaker leg indicates the front block leg.

DISCUSSION: In contrast to Vagenas and Hoshizaki (1986), we did not find any significant differences between the stronger and weaker leg positioning on the starting blocks. Thus, our main hypothesis was rejected. As the dynamically stronger leg was defined by the maximum force produced in the countermovement jumps, it was clear that there was a statistically significant difference (p=0.020) when defining stronger and weaker legs. Vagenas and Hoshizaki (1986) described how the dynamically stronger leg should be placed on the block with the higher kinetic demands; that being the front block. On the other hand, Willwacher et al. (2013) showed that better athletes produced force more equally between the blocks than lower level athletes. Thus, it could be argued that the rear foot has kinetically more demanding task and it would be important to have a stronger leg on the rear block. Although 5 out of 8 participants preferred to have their stronger leg on the rear, this did not result in a performance difference. Vagenas and Hoshizaki (1986) used experienced sprinters in their study. We deliberately included some athletes who were used to fast acceleration in their event, but not experienced using starting blocks. Interestingly, sprinters had a substantially larger number of statistically significant results between the stronger and weaker legs in their own individual performance than non-sprinters. One explanation for all of this is that sprinters have repeated the starts with their preferred block settings hundreds or thousands of times and thus they are accustomed to their specific settings. Alternating the front leg on the blocks may, thus, feel uncomfortable causing issues for the performance. Interestingly, though, there were no clear patterns that, for example, the dynamically stronger leg always produced the higher maximum

force. Non-sprinters do not have the same accustomed feeling and may consequently be a better group of athletes to analyse this type of fundamental understanding of sprint start.
The block exit velocities and maximum forces produced were slightly lower than in the Graham-Smith et al. (2014) study. This can be expected, as Graham-Smith et al. (2014) had a higher level participant than any of the athletes in this study. Further, the data were broadly in line with the range of values produced by various levels of sprinters in Bezodis et al. (2010) regarding block velocities and absolute horizontal external power calculated from a different type of data. As the results in this study are in line with the aforementioned two studies, we can be confident that our approach of correcting force production values using the inverse of finger markers' acceleration (as explained in the methods) revealed sensible values.

CONCLUSION: The results of this study raised some doubts to the previous theory of which leg should be put on the front block in the sprint start. The previous studies have used experienced sprinters accustomed to certain block settings, which may have masked the effect. It would be worth studying this issue further with participants who are used to accelerative runs, but who are taught how to use the blocks with constantly changing block settings in the training phase to avoid becoming familiar with a single block set up. Our advice for coaches training developing athletes would be to allow athletes to use the starting block settings they feel comfortable with, rather than trying to overanalyse whether the stronger leg should be on the front or rear block.

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